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AUTHOR	Watson, John L.
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ABSTRACT

The Fundamentals of Engineering (FE) project involves gaining access to data on student learning from the National Council of Examiners for Engineers and Surveyors (NCEES) that schools and programs do not normally have. This document contains an executive summary in addition to the full length report on the accomplishments of the project. The project report provides an overview of project activities and accomplishments, specific information on data collection and analysis, and the results of the faculty survey. Four appendices provide more information regarding this project. Appendix 1--Project Personnel; Appendix 2--Sample FE Examination Reports; Appendix 3--Sample of the Campus Engineering Assessment Examination; Appendix 4--Budget Expenditures. (DDR)

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ED 417 075

Quality Assurance in Engineering Education

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Rolla, MO 65401

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Project Director:

July, 1992 - August, 1995
Ellen Leininger
Director of Academic Assessment
University of Missouri-Rolla
Rolla, MO 65401

September, 1995 - December, 1996
John L. Watson
Chair & Professor
Department of Metallurgical Engineering
University of Missouri-Rolla
Rolla, MO 65401
Telephone: (573) 341-4724
E-mail: jwatson@umr.edu

FIPSE Program Officer: David Johnson

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	Year 3	$ 72,000
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	Year 5	$ 0 - No cost extension
	TOTAL	$226,000

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Project Summary

The project investigated the potential of fully using previously un-released data from the nationally normed Fundamentals of Engineering (FE) examination to assess learning in key engineering and science topics. In the past, very limited information, typically restricted to pass/fail numbers, was released by the National Council of Examiners for Engineers and Surveyors (NCEES) for the eight hour FE examination, which comprises 150-200 questions in ten morning and five afternoon topics. Thus there is a large body of data available to describe student learning in these topics and sub-topics which typically is not used by engineering programs. For the purposes of this project the NCEES agreed to release information to the University of Missouri-Rolla to permit the value of the FE data in describing student learning in key engineering and science topics to be assessed.

The analysis of the FE data was undertaken in the period 1992-1996 for students in twelve engineering disciplines at UMR. The overall conclusion of the project is that the enhanced level of data released from the FE by NCEES is of value to individual programs, schools and institutions in assessing student learning and in identifying areas of concern. However, the overall value of this information is compromised by variable student motivation and the confidentiality of the questions used in the exam. Other conclusions are that UMR student scores are below faculty expectations, that the FE exam is not equally applicable to all engineering disciplines, that the academic level of the exam may be lower than faculty thought, and that the UMR students passing rate of 75% is typically coupled with an average examination score of approximately 53%. This low FE total score raises concerns about the content of the FE examination and the level of student learning.

"Quality Assurance in Engineering Education"

University of Missouri-Rolla
Rolla, MO 65401
John L. Watson
(573) 341-4724, E-mail jwatson@umr.edu

Executive Summary

A. Project Overview for FIPSE Grant No. P116B20862-94
The FIPSE funded project entitled "Quality Assurance in Engineering Assessment" was initiated in July, 1992 with a planned completion date of June, 1995. The goal of the project was to evaluate the use of the Fundamentals of Engineering (FE) examination as an instrument for engineering schools throughout the nation to assess student learning in the core engineering and science subjects. The eight hour FE exam consists of 15 engineering and science topics, and is a major nationally normed test for engineering, but it is not taken by all engineering students, and its main value is as step in the process of attaining professional registration. A further problem with the FE examination is that only individual discipline pass/fail data is released to engineering schools. Thus it is difficult to assess student learning and to identify areas of curricula concern when discipline pass/fail data is the only information provided from a lengthy, comprehensive test.

Through an agreement with the National Council of Examiners for Engineers and Surveyors (NCEES), the University of Missouri-Rolla (UMR) undertook a project, funded by a Department of Education FIPSE grant, to analyze complete data released for students in twelve UMR engineering disciplines, detailing performance on individual questions in each topic and sub-topic of the FE exam. The analysis of FE data from the period 1992-96 was undertaken with the aid of students and faculty in the School of Engineering and the School of Mines and Metallurgy.

The outcomes of the project are that the UMR campus is now more fully aware of the nature and value of the FE examination, and of the potential value of the additional information that was released to the FIPSE project. It is apparent that there are problems associated with interpreting the FE data due to variable levels of student motivation. Such problems could not be overcome without full student cooperation which could probably only be achieved by a mandatory pass requirement by engineering programs. The project established that only a poor correlation existed between FE score and student GPA, and that students in disciplines where professional registration is important have greater success on the FE exam. Engineering topics where students had problems were identified, but appropriate feedback was very difficult due to the absence of detail of the individual questions. Finally a campus examination was devised with known questions, and the results of that examination were correlated with the subsequent FE morning results for a small volunteer student group. The lower than anticipated performance of that student group on the campus test, coupled with the subsequent FE results, suggests that the FE

morning examination is not at as high a level as faculty had surmised from the available sample FE questions. This in turn raises the question of the level of student learning when an average score on the FE morning examination is typically 50-55%.

B. Purpose

The purpose of the project was to assess the value of complete FE examination data to engineering programs in evaluating student learning in key engineering and science topics. The project was designed to examine the individual student performance on each question in each of the 15 FE exam topics, and to attempt to establish the value of such data in assessing student learning, and thus to establish quality assurance for engineering education in a given program.

C. Background and Origins

The Fundamentals in Engineering (FE), or Engineer in Training (EIT), examination in many respects is the only engineering assessment instrument in current use by accredited engineering schools. The FE is a national exam operated by the National Council of Examiners for Engineering and Surveying, and is given twice yearly in November and April. Although many engineering programs encourage their students to take the FE exam, very few make it mandatory. The major motivation for students to take the FE exam is as a required step in professional registration, a qualification that has major value in some disciplines and none in others. As a result of security and confidentially issues, the only examination information typically received by individual engineering programs from the NCEES is the number of students who passed and who failed. The names of individual students and their overall scores are not released, and further the examination questions are not disclosed at any time. Thus FE pass rates are the major nationally norm-based measure of quality available to engineering programs. Since the FE exam is a comprehensive examination consisting of 150-200 questions and taken by up to 30,000 students, there is an enormous quantity data which could be potentially invaluable to engineering schools.

A common criticism of the FE is that not all programs include all of the examination topics in their curricula, and hence an interpretation of results is difficult between different engineering disciplines. In addition, a comparison between the same disciplines at different institutions is also very difficult as many institutions do not make the exam mandatory. Finally the lack of information on the individual questions comprising the FE obviously detracts from the value of any resulting data for the purpose of assessing quality of engineering undergraduate education.

D. Project Description

The UMR FIPSE project acquired detailed information on individual UMR student performance on each question of each topic of the FE examination from NCEES over the period 1992-96. Individual student examination data were only provided to UMR for students who signed a release form authorizing the transfer of information. This information formed the basis of the project and was analyzed in terms of individual student performance by examination topic and by individual topic question to provide data to assist programs to assess student learning, to identify performance on discipline specific relevant topics, and to identify areas of the examination in which students performed poorly, adequately and exceptionally. In addition, programs then provided estimates of their expectations for their students in the topics and sub-topics of the FE such that a comparison of expectations and performance could be made.

With the released FE examination data, it was possible for the project to provide data to faculty, acting as project coordinators and facilitators for each engineering program, each school and the campus, detailing discipline pass rates, individual student success rates on each topic, and success rate on individual questions. This data were then analyzed by the project coordinators and facilitators at the program and school levels, and appropriate conclusions drawn.

E. Evaluations/Project Results

The data produced by the project for a total of 1600 students revealed that there are several problems in analyzing the FE examination results. Firstly because the students taking the exam have different levels of motivation, the results do not necessarily reflect student learning. At UMR, all engineering students are required to take the FE exam, but they are not required to pass it. Most universities do not require students to even take the FE. A poor correlation was determined for FE score with campus GPA, and the correlation varied significantly for individual disciplines. The project confirmed that student success in the FE is impacted by the importance of professional registration to future careers. The data also provided indications of topics in which UMR students had difficulties, but in general these were topics in which students nationally did poorly. Although the project data identified areas of curriculum concern, it was not possible to implement appropriate feedback due to the complete confidentiality applied to the FE individual questions. The cause of poor student performance could not be identified and could be a function of poor student learning, the difficulty of the question, or a poorly worded or obscurely focused question. A further project revealed that the long held assumption that students in some disciplines were significantly disadvantaged by the presence of topics on the FE, which were not covered in the program curriculum, was only partially supported. Finally an analysis of faculty expectations and student performance revealed that students were scoring below the expected level, and on an instrument that appeared significantly easier than faculty were led to believe from sample FE questions. A campus assessment was devised and a correlation established between the campus instrument and the FE. The correlation suggests that the WS 96 FE examination was pitched at a somewhat lower standard than faculty assumed, and thus the level of engineering learning for UMR students was in question with an average FE score of 52%, coupled with a FE pass level of 42% and a 76% pass rate.

F. Summary and Conclusions

The project generated and analyzed a great deal of data that had previously not been available to engineering programs. It is apparent that the analysis of FE data is complicated by student motivation, and by discipline curricula. As result, FE scores were poorly correlated with student GPA, and FE scores were higher for discipline where professional registration was important. The additional FE examination data released by the NCEES did provide an insight into engineering and science topics on which students encountered problems, but appropriate feedback was virtually impossible because exam confidentiality precluded knowledge of the questions that caused student difficulties. As a result of a comparison between the student scores on the morning topics of the WS 96 FE exam and a campus engineering assessment exam, it is suggested that average student score of 52% on the morning FE is questionably low.

FIPSE Grant No. P116B20862-94

"Quality Assurance in Engineering Education"

University of Missouri-Rolla
Rolla, MO 65401
John L. Watson
(573) 341-4724, E-mail jwatson@umr.edu

Project Report

A. Project Overview

The FIPSE funded project entitled "Quality Assurance in Engineering Assessment" was commenced in July, 1992 with an initial completion date of June, 1995. The goal of the project was to evaluate the use of the Fundamentals of Engineering (FE) examination as an instrument for engineering schools throughout the nation to assess student learning in core engineering and science topics. The FE exam is the major nationally normed test for engineering, but it is not taken by all engineering students, and only pass/fail data from the FE examination is released to engineering schools. The FE exam consists of 15 topics with approximately 150-200 total questions, and hence there is a considerable amount of detailed information generated each year for the 30,000-50,000 students who take the exam. As result of strict confidentiality, the vast majority of the exam data is not released, and hence the value of the FE exam in assessing student learning and engineering curricula is very limited. Through an agreement with the National Council of Examiners for Engineers and Surveyors (NCEES), the University of Missouri-Rolla (UMR) received a Department of Education FIPSE project grant to analyze comprehensive data released for UMR students in twelve engineering disciplines. The released data detailed student performance on individual questions in each topic and sub-topic of the FE exam. This project represented the first time that an analysis of complete FE data had been undertaken.

The original project PI was Dr. Ellen Leininger, Director of Academic Assessment at UMR, who resigned from the university in 1995 after completing the three years of the project and seeking and being granted a no-cost extension through the end of 1995. A project coordinator (5%FTE) with no budgetary responsibility, Dr. John L. Watson, Chair of Metallurgical Engineering, was then appointed to oversee the completion of the project. After reviewing the status of the project and the tasks still to be completed, Dr. Watson requested and received a further no-cost project extension through December, 1996.

The project evaluated the UMR student FE data for the period FS92 through WS96, and selected the following areas for analysis:

1. ***FE pass rate data*** - an examination of the morning, afternoon and total FE scores as a function of semester, discipline, school, campus, and student GPA.

2. Specific topics data - an examination of the morning and afternoon topic scores by discipline.

3. Discipline-specific topics - an investigation of the scores calculated for an evaluation based on FE topics selected by disciplines as being specifically relevant to the discipline.

4. Topic areas of satisfaction and concern - identification of topics and sub-topics in which the average UMR student scored above 75% or below 25%

5. Faculty expectations - an examination of the performance of students on FE topics with respect to faculty expectation in those areas.

6. A campus engineering assessment exam - an evaluation of the performance of a student volunteer group on a campus exam in relation to results from a subsequent morning FE exam for the same student group.

7. Curriculum-based indicators of FE performance - an investigation of the relationships between student FE scores and their campus performance in specific courses or groups of courses for an individual discipline.

The outcomes of the project are that the UMR campus is now more fully aware of the nature and value of the FE examination, and of the potential value of the additional information that was released to the FIPSE project. It is apparent that there are problems associated with interpreting the FE data due to variable levels of student motivation. Such problems could not be overcome without full student cooperation which could probably only be achieved by a mandatory pass requirement by engineering programs. The project established that only a poor correlation existed between FE score and student GPA, and that students in disciplines where professional registration is important had greater success on the FE exam. The widely held belief that some disciplines were significantly disadvantaged by the nature of the FE topics was only partially supported. FE topics where students had problems were identified, but appropriate feedback was very difficult due to the absence of detail of the individual questions which caused the problems. Students were shown to perform below the level of faculty expectations, which were based on typical sample questions published for each FE topic. The results of a campus examination with known questions were correlated with the subsequent FE morning exam results for a small volunteer student group, and the lower than anticipated performance of that student group on the campus test, in comparison with the subsequent WS 96 FE results, suggests that the FE morning examination is not at the level faculty had surmised from the available sample FE questions. This in turn raises the question of the level of student learning when the average score on the morning FE examination is less than 55%, and is even lower on the afternoon examination.

B. Purpose

The purpose of the project was to assess the value of FE examination data to engineering programs in evaluating student learning in key engineering and science topics. Since the FE examination is the major engineering assessment instrument and has an eight hour, 15 engineering and science topic format, it was considered that a great deal of valuable information was contained within the students answers to the FE questions. The FE examiners only release pass/fail data to engineering programs, and do not identify successful candidates. To permit an analysis of FE data, the project requested full release of FE exam data from NCEES for UMR engineering students in twelve disciplines for a period of three years. The project was designed to examine the individual student performance on each question in each of the ten morning topics and five afternoon topics, and to attempt to establish the value of such data in assessing student learning, and thus to establish quality assurance for engineering education in a given program.

C. Background and Origins

The Fundamentals of Engineering, or Engineer in Training (EIT), examination in many respects is the only engineering assessment instrument in current use by accredited engineering schools. The FE is a national exam operated by the National Council of Examiners for Engineering and Surveying, and is given twice yearly in November and April with between 15,000-25,000 students taking each offering. The major use of the FE exam is as a required preliminary qualification in the process of attaining professional engineer status, and the exam is typically not mandatory and has variable value to individual engineering disciplines. The FE exam assesses student performance in ten topics in the first or morning exam, and five topics in the second or afternoon exam. The morning topics consist of Chemistry, Fluid Mechanics, Dynamics, Electrical Circuits, Engineering Economics, Materials Science/Structure of Matter, Mathematics, Mechanics of Materials, Statics, and Thermodynamics, with the afternoon session comprising Applied Mathematics, Electrical Circuits, Engineering Economics, Engineering Mechanics, and Thermodynamics/Fluid Mechanics. These topics cover all aspects of engineering, but the importance of some topics to all individual disciplines is questionable, and there are examples of engineering curricula not containing courses covering some of the topics. In the project period the exam has approximately 150-200 multiple choice questions with five alternative answers provided for each question. The number of questions in the morning and afternoon examinations has varied between 105 and 140, and 52 and 70 respectively. Each afternoon question has double the value of each morning question in determining the final raw score, which has thus varied between 209 and 280. A scaled score is calculated by NCEES from the raw score for each student.

As a result of security and confidentially issues, the only examination information typically received by individual engineering programs or disciplines (mechanical, civil, electrical, chemical etc.) is the number of students who took the exam, the number that passed, the number and pass rate for all engineering programs in their institution, and the number and pass rate for all similar disciplines at other institutions. The names of individual students and their overall scores are not released, and further the examination questions are not disclosed at any time. Due to a lack of alternative data, FE pass rates are regarded as a major nationally normed measure of quality, but with so little detail available to assist programs to identify areas of poor performance and/or concern in their curricula, the value of the FE data is very limited.

Average FE results for UMR students and for all engineering students for 1992 are shown in Table 1, and it can be seen that scores on the morning session were 55-62%, while the afternoon scores were lower. The total exam score, calculated with the afternoon questions carrying double weighting, is approximately 55% for all students, and this corresponds to a pass rate of

Table 1 - Average UMR FE Exam Score Data for 1992

FE Exam	April, 1992		October, 1992	
	UMR	ALL	UMR	ALL
Morning Score (%)	61	62	55	55
Afternoon Score (%)	51	51	51	53
Total Score (%)	55	56	53	54
Pass Rate (%)	73	71	66	65

approximately 69% for the 21,600 total candidates. Generally speaking, the data infer that students need to answer less than half of the questions correctly on the morning and afternoon sessions to pass the exam. If this is the case, the content of the FE exam appears to contain a significant amount of material that the students have not mastered and need not master to attain the first qualification on the path to professional registration. The passing score is low probably to take account of students doing poorly on areas that are not important to their discipline, and for which their education has not prepared them. However, since the FE data typically released has been extremely limited, the true value of the exam has not really been assessed. In addition, as the FE examination questions themselves are never published, engineering faculty do not know the level of learning necessary to answer 50% of the questions correctly, and they can only assess the level in terms of sample questions published by NCEES.

As mentioned above, not all engineering programs include all of the FE examination topics in their curricula, and hence an interpretation of FE results is difficult between different engineering disciplines. In addition, a comparison between the same disciplines at different institutions is also very difficult as many institutions do not make the exam mandatory.

In the light of the above comments, this project was initiated to investigate the topics identified above, and to assess the value of the huge amount of FE examination data as a measure of quality assurance in engineering education.

D. Project Description

The UMR FIPSE Project, initiated in 1992, acquired detailed information on individual UMR student performance on each question of each topic of the FE examination from NCEES over the period 1992-96. Individual student examination data was only provided to UMR for students who signed a release form authorizing the transfer of information. This information formed the basis of the project and was analyzed in terms of individual student performance by examination topic, and by individual topic question, to provide data to assess learning in engineering and science topics, and to assist programs to identify areas of the examination in which students performed poorly, adequately, and exceptionally. In addition, programs also estimated their expectations for their students performance on the topics and sub-topics of the FE, such that a comparison of expectations and performance could be made. Other areas investigated included appropriateness and impact of specific FE topics, the relationship between results for a known engineering assessment (CEA) and those from the FE morning topics, and possible dependance of FE results on grades achieved by students in campus courses or groups of courses.

a) Personnel

Dr. Ellen Leininger, the UMR Director of Academic Assessment and Student Research, was the Principal Investigator on the project through the course of the original time period (1992-95). Other personnel involved in the project include the coordinators, listed in Table A1 in Appendix A, the facilitators listed in Table A2 in Appendix A, and Dr. James Valentine, a UMR Research Analyst, who generated data from the NCEES disks. Each of the ten engineering departments on campus was represented by a faculty member and seven of the ten chairs were active as coordinators. The other chairs together with representatives of the three schools formed the facilitator group. Thus the importance of the project to the campus was evident, and this was further reinforced by the inclusion of Deans, the Vice Chancellor for Academic Affairs, and the Chancellor, in all data distributions.

With Dr. Leininger's resignation from UMR in 1995, Dr. John L. Watson, Chair of Metallurgical Engineering, assumed responsibility for completing the project with the assistance of five of the original coordinators (Dr. Shala Keyvan, Nuclear Engineering; Dr. Douglas Mattox, Ceramic Engineering; Dr. Robert Medrow, Mechanical and Aerospace Engineering; Dr. Paul Munger, Civil Engineering; and Dr. Keith Stanek, Electrical Engineering). Dr. Watson devoted 5% of his time to the project, but did not have responsibility for the budget which remained within the Vice Chancellor for Student Affairs.

b) Schedule

The project was initially scheduled for three years, but due to unforeseen problems with receiving and formatting data, the timetable was extended. The following is an approximate schedule for the project:

Fall Semester 1992	Data processing
Winter Semester 1993	Data analysis of FE FS92 Levels 1 & 2
Fall Semester 1993	Data analysis of FE WS93 Levels 1 & 2
Winter Semester 1994	Data analysis of FE FS93 Levels 1 & 2
Fall Semester 1994	Data analysis of FE WS94 Levels 1
Winter Semester 1995	Data analysis of FE FS94 Levels 1 & WS94 Level 2
Fall Semester 1995	Data analysis of FE FS94 Level 2 & WS95 Level 2 & 3
Winter Semester 1996	CEA development and data analysis of FE FS95 Level 1
Fall Semester, 1996	Data analysis of FE FS95 Level 2&3, & WS96 Levels 2&3
January , 1997	Final report preparation

c) Acquisition and Analysis of Data Procedures

As the NCEES would only release FE examination data to the project for students who had signed information release forms, project coordinators and facilitators endeavored to ensure that compliance rates for data release were as high as possible. The NCEES provided FE data to UMR on computer disks, and considerable difficulty was encountered in processing, checking and formatting the data for distribution to project participants on campus. Significant delays were encountered and considerable campus effort was expended in this phase of the project. The data eventually produced in this manner for each FE exam formed the basis of the project, and it was then possible for three levels of data to be provided to each engineering program, school and campus. Level 1 data was that typically provided to each program by NCEES giving student numbers, and pass rates for the discipline, all UMR engineering programs, and all similar programs. Level 2 data provided the number of questions answered correctly for each individual student for each of the 15 topics of the examination. Finally Level 3 data covered the results for each question in each topic on a program, school and campus basis. Examples of the three level reports are presented in Appendix B.

The distributed data provided an analysis in terms of individual student performance by discipline, by examination topic, and by individual topic question for the project facilitators and coordinators. The project evaluated the UMR student FE data for the period FS93 through WS96, in the following areas:

1. ***FE pass rate data*** - an examination of the morning, afternoon and total FE scores for FS93 through WS96 as a function of semester, discipline, school, and campus, and student GPA.

2. ***Specific topics data*** - an analysis, by discipline, of the morning and afternoon topic scores to produce statistical data for the campus illustrating the topics in which students from individual disciplines do well or poorly.

3. ***Discipline-specific topics*** -each discipline coordinator was requested to consult with faculty colleagues to devise a discipline specific topics (DST) examination consisting of only those topics of the FE examination that were considered specifically relevant to their degree program. Then, using data from the WS94, FS95 and WS95 FE exams, student scores for the DST exam were determined and compared with corresponding scores on the FE morning exam for each discipline.

4. ***Topic areas of satisfaction and concern*** - an analysis identified topics and sub-topics in which the average campus student scored above 75% or below 25% in two of the five semesters (WS94 through WS96) for which Level 3 data was analyzed.

5. ***Faculty expectations*** - an examination of the performance of students on FE topics, with respect to faculty expectation in those areas, was undertaken by several department coordinators for the data from WS94, FS94 and WS95.

6. ***A campus engineering assessment exam*** - the CEA was devised by a group of project coordinators, namely Dr. Shala Keyvan, Nuclear Engineering; Dr. Douglas Mattox, Ceramic Engineering; Dr. Robert Medrow, Mechanical and Aerospace Engineering; Dr. Paul Munger, Civil Engineering; Dr. Keith Stanek, Electrical Engineering; and Dr. John Watson, Metallurgical

Engineering. The CEA was designed to simulate the ten morning topics of the FE examination using questions devised by the group. The 40 questions were formulated with the anticipation that the average UMR student would score 75-85% on the test. A copy of the CEA is given in Appendix C. The CEA was administered to a volunteer group of UMR students under similar conditions to those used for the April 96 FE examination which was given two weeks later.

*7. **Curriculum-based indicators of FE performance*** - an investigation of the relationships between student FE scores and their campus grades in specific courses or groups of courses was undertaken for civil engineering by Dr. Paul Munger for the WS96 FE data.

E. Evaluations/Project Results

The data generated by the project for 1600 UMR students was released to programs and schools through funded project coordinators, who represented the individual engineering departments, schools, and the non-engineering disciplines, such as math, physics and chemistry, with a technical involvement in engineering education. The coordinators provided feedback for the project and assisted with release form administration, analysis of data, and discussion of results.

a) Student Compliance Rate

The compliance rate for students releasing test data to the project is indicated in Table 2 for the

Table 2 - Compliance Rate for Student Release of FE Data

Department	**1992-93 Rate %**	**1993-94 Rate %**	**1994-95 Rate %**
Aerospace	100	100	93
Ceramic	94	100	100
Chemical	96	98	100
Civil	96	100	98
Electrical	72	81	70
Engineering Mgt	76	66	59
Geological	100	100	100
Mechanical	99	98	100
Metallurgical	100	100	100
Mining	100	92	100
Nuclear	100	91	100
Petroleum	100	100	100
CAMPUS	**90**	**93**	**90**

period 1992 through 1995, and it can be seen that the majority of the 12 departments had a compliance rate over 90%, with an overall campus compliance rate averaging better than 90%. With the released information, it was possible for the project to provide analytical data to each engineering program, school and campus for the FE topics and sub-topics.

b) Campus and Discipline FE Pass Rate Data 1993-1996

The average UMR FE raw score (%) data collected for FS 93 through WS 96 are presented in Table 3, and it can be seen that on average 76% of UMR students passed the FE exam, and that

Table 3. - FE Raw Scores for FS93 through WS96.

Examination	**FS93**	**WS 94**	**FS94**	**WS95**	**FS95**	**WS96**	**Ave**
AM Raw Score (%)	57	60	59	49	49	53	**56**
PM Raw Score (%)	57	52	50	47	49	49	**51**
Total Raw Score (%)	57	55	53	48	49	50	**52**
Pass Rate %	75	77	76	76	75	76	**76**

the weighted average total raw score was 52%. The 1994 data were shown to be normally distributed with a standard deviation of 14%, and thus it can be inferred that for the period 1993-96 the lowest passing score for UMR students having a mean score of 52% and a pass rate of 76% would be 43%. This may be interpreted to show that students may pass the FE even if they have not learned the required material for over half of the questions.

The FE pass rate and student numbers data for all students who signed a FE score release form are presented in Table 4 by engineering discipline for the period 1993-96. It can be seen that pass rates remain around the 76% level, and it is pertinent to note that the major engineering disciplines of civil, electrical, and mechanical engineering typically have pass rates in excess of 80%. The smaller departments with degrees in more specialized areas, such as chemical, metallurgical and mining engineering, tend to have very variable pass rates, which are somewhat below those for the major engineering programs. This has been explained in the past by the effect of small student numbers and by disciplines suggesting that the FE exam does not reflect their curriculum, and that the exam is skewed towards topics emphasized in the major engineering disciplines. An examination of the 15 topics of the FE exam does suggest that a significantly large proportion of questions are devoted to areas to which some programs devote only one three hour course in a curriculum of over 130 hours. Examples of this are electrical circuits, thermodynamics, and fluids, all of which are found in two out of the 15 FE topics. This situation has prompted recent changes in the format of the FE which will retain the current morning topics, but provide subject specific topics for chemical, civil, electrical, industrial, and mechanical engineering in the afternoon session. All other disciplines will retain the current format, which is

Table 4 - UMR FE Pass Rate and Student Numbers by Discipline 1992-96

Discipline/Year	1993-94	1994-95	1995-96
Aerospace	94 (17)	83 (6)	86 (14)
Ceramic	61 (18)	83 (6)	73 (11)
Chemical	79 (61)	61 (41)	67 (50)
Civil	84 (108)	81 (94)	85 (124)
Electrical	92 (90)	90 (60)	97 (68)
Engineering Mgt	51 (35)	65 (40)	39 (36)
Geological	44 (45)	49 (35)	40 (53)
Mechanical	85 (176)	93 (108)	87 (125)
Metallurgical	60 (25)	60 (20)	90 (10)
Mining	33 (15)	67 (12)	60 (25)
Nuclear	100 (6)	100 (14)	93 (15)
Petroleum	25 (16)	18 (11)	39 (18)
CAMPUS	**76 (612)**	**77 (447)**	**75 (549)**
NATIONAL	**80**	**69**	**72**

somewhat contrary as those disciplines are probably the ones really meriting reformatting. From Table 4, the campus data appear not to reflect national data, and one reason may be that UMR requires all engineering students to take the FE examination, while in the majority of engineering schools the examination is voluntary and is mainly taken only by those students who consider the professional engineer qualification important to their future careers. Typically civil, electrical, and mechanical engineers are the disciplines where the PE title has greater importance.

Initially, each of the engineering discipline coordinators examined their student data for WS94 and FS94, and looked for correlations with student GPA, individual course performance or groups of courses performance. The campus results for students in the 12 engineering disciplines are shown in Figure 1, which plots student FE raw score against GPA for students taking the FE in WS94 and FS94. The correlation coefficient (r^2) for the data is 0.25 with 450 data points, and it is obvious that there is a general trend of increasing FE score with increasing GPA. Individual departments generated correlation coefficients varying from 0.00 (Mining Engineering) to 0.96 (Ceramic Engineering), but both of these relationships were established using a small number of

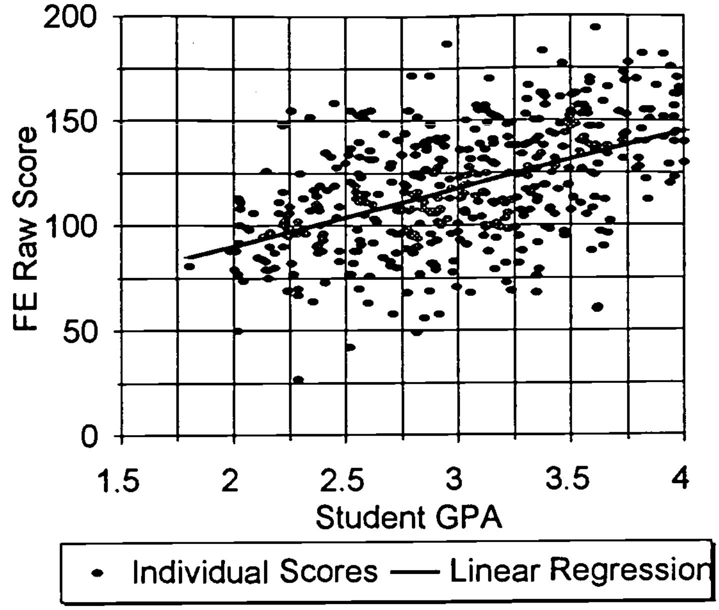


Figure 1. UMR FE Raw Score v. Student GPA for WS94 & FS94

students. For the larger departments (Civil, Chemical, Electrical, and Mechanical), the correlation coefficients varied from 0.18 to 0.53. Overall it is evident, as would be expected, that FE score loosely correlates with GPA for individual students, and it appears that a better relationship exists for departments in which professional registration is important and hence students are more motivated to succeed. Civil engineering is typically held as the degree for which the FE has most value, and the overall correlation coefficient for 104 students was 0.42 which is higher than the values for Mechanical (0.31), Electrical (0.30) and Chemical Engineering (0.24).

c) Specific Topics

To illustrate the FE performance by topic and by discipline, Tables 5a & b present the average raw score percentages for the morning and afternoon examinations respectively for WS94 through WS96. The average score for morning topics ranges from 42% in Mechanics of Materials to 61% in Chemistry, while the afternoon averages range from 36% for Electrical Circuits to 56% for Applied Mathematics. The range of standard deviations for student scores in individual topics is 19% (Mathematics) to 26% (afternoon Engineering Economics). As would be expected there are some topics in which individual disciplines excel and some in which individual disciplines perform very poorly. Electrical engineering students should and do score very well in electrical circuits in both the morning and afternoon topics, and in fact outscore all other disciples by over 20% on both topics. The materials disciplines and chemical engineering students likewise score well in chemistry, as do civil and mechanical engineering students in statics and mechanics, and ceramic, metallurgical and nuclear engineering students in materials, but none by the large margin seen for circuits. Similarly circuits, dynamics, thermodynamics and mechanics of materials are topics in which several disciplines do poorly, simply as a function of those topics not being considered sufficiently relevant to the discipline to warrant emphasis. It appears that recognition of such discipline disadvantageous topics is the reason why the pass rate is in the order of 70% even

Table 5a. WS94 through WS96 Program Topics AM Test Scores (%)

	AM Topics									
Discipline	**Chem**	**Circ**	**Dyn**	**Econ**	**Fluid**	**Math**	**Mats**	**Mech**	**Stats**	**Therm**
AE	60	47	61	46	48	65	59	51	58	64
CER	72	52	50	52	48	55	71	41	49	50
CIV	51	38	49	76	59	53	49	60	65	40
CHEM	77	48	49	74	58	57	59	28	43	60
EE	59	79	63	57	36	72	58	26	58	50
EMGT	47	45	44	66	36	47	50	34	44	40
GE	56	52	47	52	51	48	56	43	52	30
ME	57	48	60	66	58	63	60	55	62	59
MET	77	45	38	61	44	58	74	41	56	50
MIN	55	42	47	72	49	46	55	41	52	40
NUC	69	57	59	51	62	74	80	49	59	67
PET	56	38	41	42	45	60	42	37	42	47
AVE	**61**	**49**	**51**	**60**	**50**	**58**	**59**	**42**	**53**	**50**

Table 5b. WS94 through WS96 Program Topics PM Test Scores (%)

	PM Topics				
Discipline	**Applied Math**	**Elec. Circuits**	**Eng. Econ.**	**Eng. Mechs**	**Thermo/Fluids**
AE	62	32	40	47	36
CER	52	37	44	41	36
CIV	53	31	72	50	51
CHEM	61	40	64	33	49
EE	73	72	50	40	40
EMGT	49	33	59	30	33
GE	47	29	48	36	41
ME	66	40	63	51	51
MET	53	29	55	39	37
MIN	45	26	60	33	37
NUC	66	42	57	47	47
PET	47	27	34	27	34
AVG	56	36	54	40	41

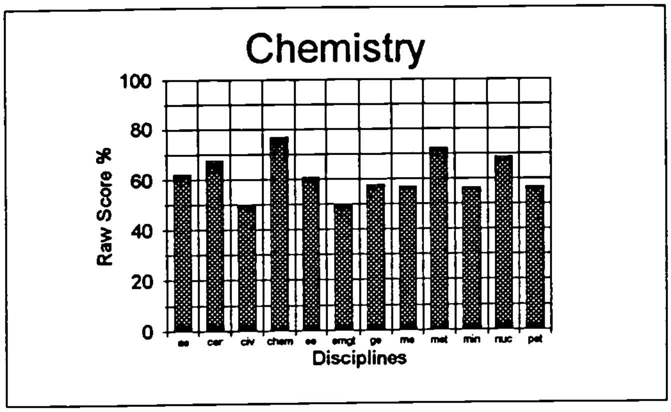
though the overall average raw score for the FE is typically only in the order of 50-55%. Figures 2a, b, & c present the discipline data in bar chart form for WS94 through WS96.

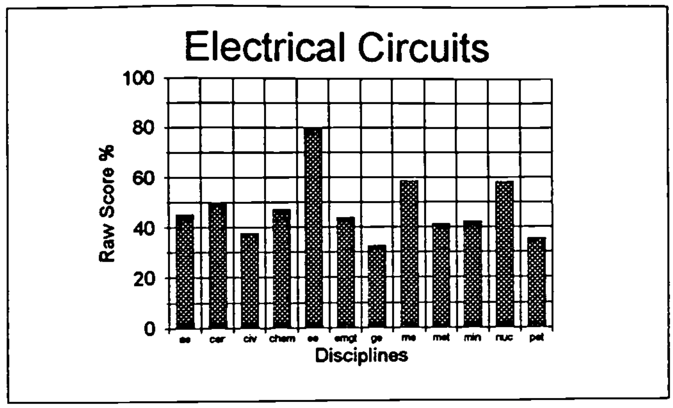
d) Discipline-specific Topics

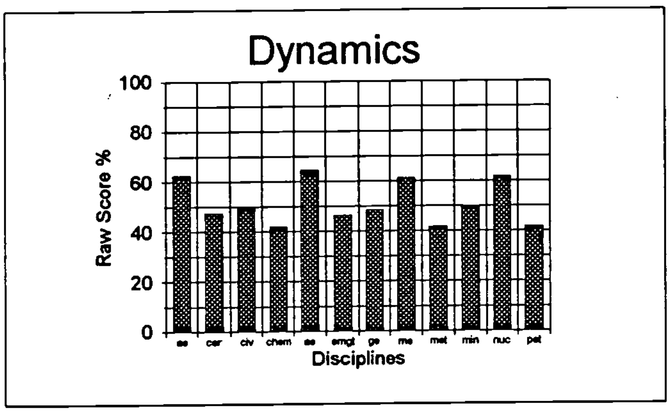
For some time, faculty in the smaller engineering disciplines have considered that the FE examination was not equally relevant to all disciplines, and that specific FE topics were inappropriate to their curriculum. It is evident from the above data that certain disciplines are advantaged by the topic distribution of the FE exam, especially those for which highly relevant and curriculum emphasized topics appear in both the morning and afternoon session. Typical examples cited include many disciplines only taking one electrical circuits, electrical engineering not having a fluids_course, and metallurgical engineering not having a dynamics course. Such conditions were thought to detract from the performance of students on the full FE exam. To examine the possible impact of the apparent unfairness, each discipline constructed an examination comprised of topics that the discipline thought of major importance to their degree program. The programs then examined their student performance using only the program designated specific topics (DST), and the results of this analysis for the three semester period WS94-WS95 are given in Table 6. The table also details the topics that each program elected to omit and it is apparent that, in the view of several programs, circuits, statics, dynamics, fluids and economics were not considered to have a major relevance, and thus had received reduced or

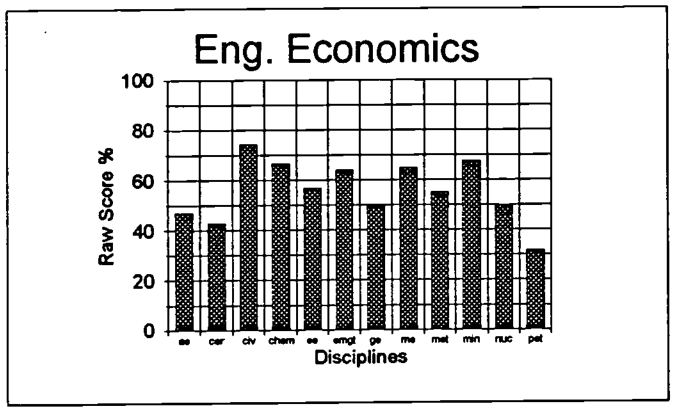
Table 6. WS94/FS94/WS95 Program Specific Topics Test Scores

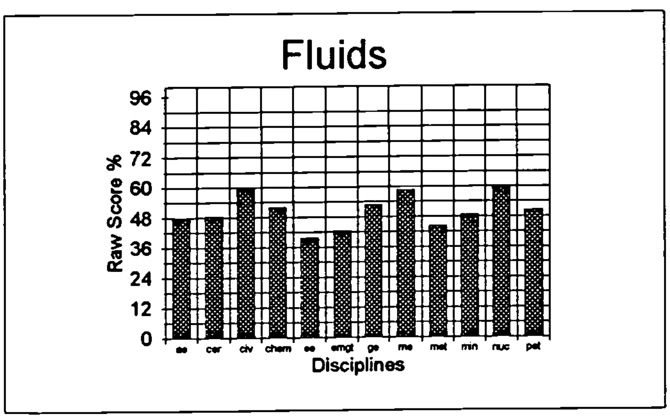
Discipline [major]	Average FE %	Average DST %	Change %	AM Topics Omitted	PM Topics Omitted
AE	55.7	58.1	2.4	Chem,EE,Econ,Mat	EE,Econ
CER	49.8	49.3	-0.5	Dyn,EE,Fld	EE
CIV	54.0	65.0	11.0	Ecn,Fld,Stat	Econ,Flmc
CHEM	NA	NA	NA	NA	NA
EE	60.2	68.0	7.8	Fld,Mch	Fls,Enmc
EMGT	NA	NA	NA	NA	NA
GE	45.0	55.2	10.2	Dyn,Ecn,EE,Fld ,Mch,Stat	Ecn,EE,Enmc,Fld
ME	59.4	59.7	0.3	Chm,Ecn,EE,Mat	EE,Econ
MET	48.7	54.5	5.8	EE,Dyn,Thm	EE,Emnc
MIN	46.9	49.8	2.9		EE,Flmc
NUC	59.4	64.0	4.6	Chem,Dyn,Econ,EE,Stat	Econ,EE,Enmc,Fld
PET	38.4	49.1	11.7	Dyn,Econ,EE,Fld,Stat	Econ,EE,Emnc,Fld











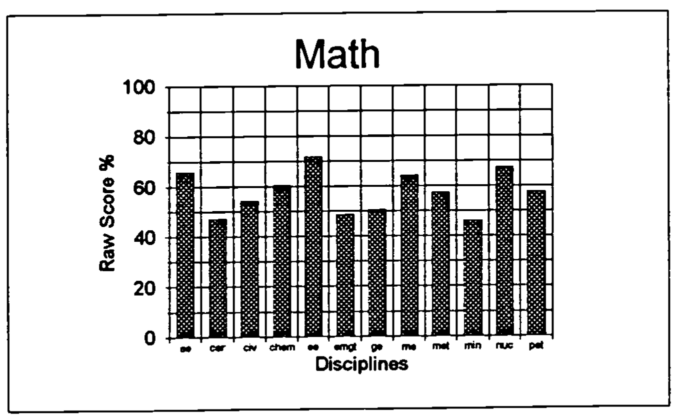


Figure 2a - FE Morning Topic Raw Scores (%) by Discipline

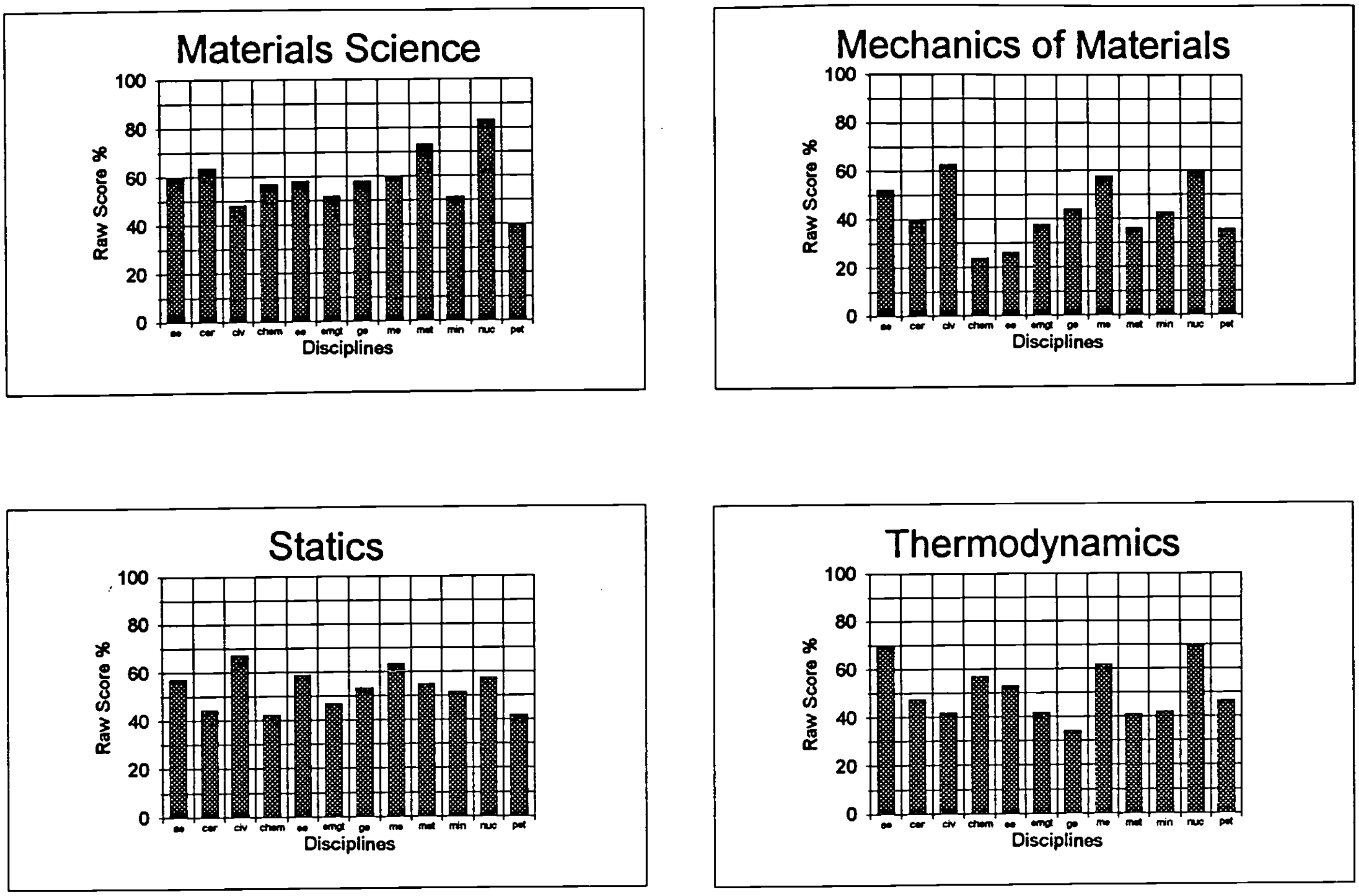


Figure 2b - FE Morning Topic Raw Scores (%) by Discipline

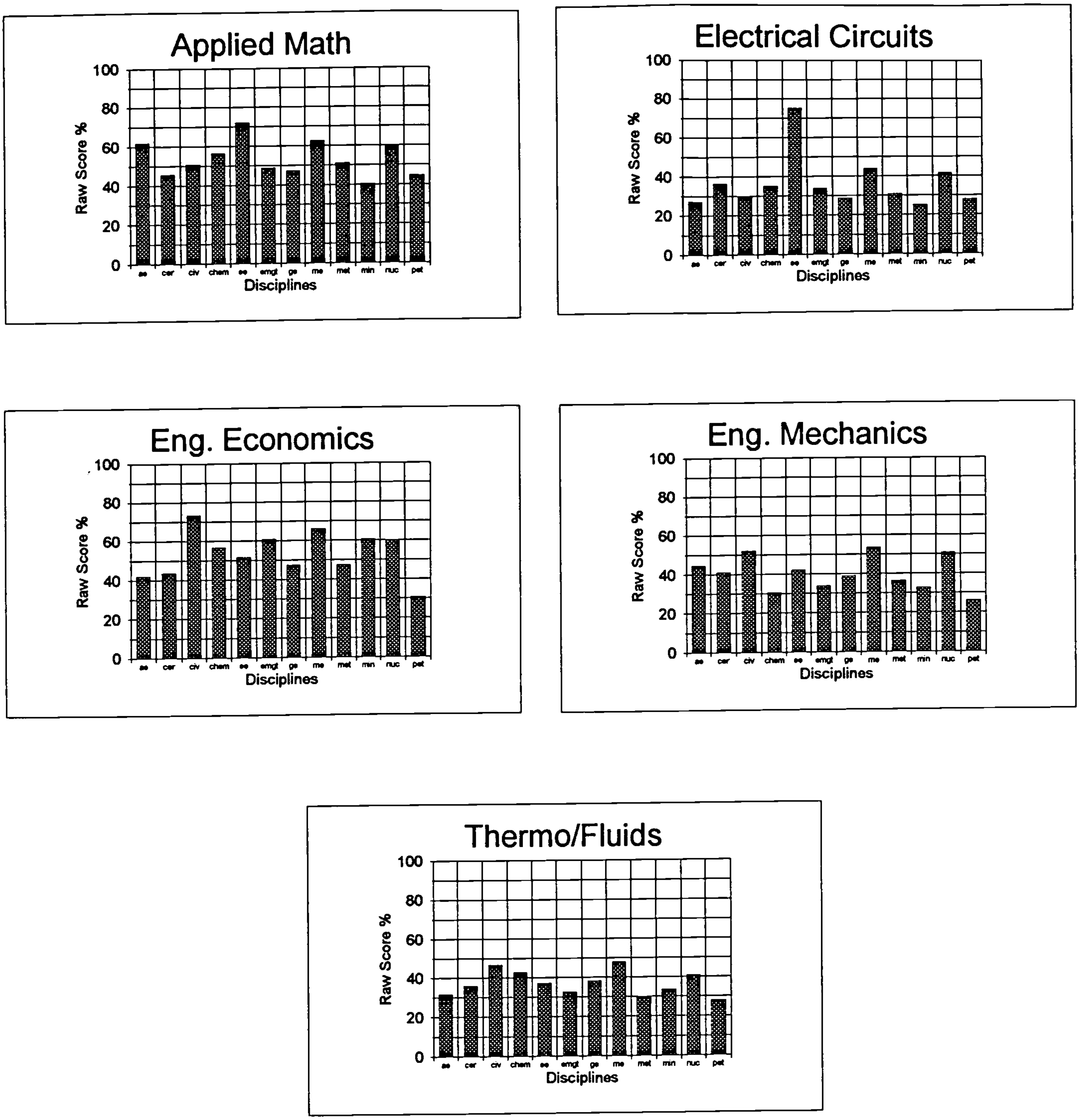


Figure 2c - FE Afternoon Topic Raw Scores (%) by Discipline minimal coverage in the curriculum. An examination of the results in Table 6 clearly shows that student performance was not enhanced significantly by discounting "non-relevant" topics. The weighted average department score increase was in the order of 5% ,with only civil, geological, and petroleum engineering showing an increase of greater than 10%. This would appear to indicate that the presence of topics not considered of primary importance to a program does not greatly alter student scores, and might not significantly alter success rates for a given program. It is interesting to note that in one case students actually performed better on the full FE exam rather than the specific topics exam selected by the faculty.

e) Identifying Areas of Satisfaction and Concern

In terms of identifying areas of satisfaction and concern, initial results indicated that coordinators could use the data generated by the project to identify topics in which students performed above, at, or below expectations. However it was not possible to identify the root cause of the problem areas as the nature of the questions was not available. Overall for the campus, it was apparent that electrical circuits, mechanics of materials, dynamics, thermodynamics and fluids were areas where students had difficulties. However, national data indicates that these are areas where students typically score less than 50%. UMR engineering students do very well on chemistry, economics, and mathematics, and score above the national averages on these topics.

From the WS 94 through WS 96 FE results, the project generated Level 3 data which provided individual question statistics for disciplines, schools and the campus. Table 7 presents the sub-topics for which the average UMR student scored above 75%, or below 25%, in two of the five semesters for which data were examined. It can be seen that there are few sub-topics

Table 7. Level 3 Data Analysis for Sub-Topics for WS 94 through WS 96

Topics	Sub-Topics > 75%	Sub-Topic < 25%
Mathematics	Analytical geometry, Differential calculus, Integral calculus	Differential equations Probability & statistics
Materials	Processing & testing	
Chemistry	Periodicity	Oxidation & reduction States of matter
Mechanics of materials		Shear, stress & strain, frames
Engineering economics	Break even analysis, Present worth, Future worth	
Thermodynamics	Phases	Cycles
Dynamics		Work & energy
Electrical Circuits	Direct current circuits	Transients Electricity & magnetism

where such criteria are met, and there are frequent examples of subtopics appearing in both categories. Thus the inference is that sub-topic questions are variable in difficulty level or that instruction is not consistent. It is again apparent that without knowledge of individual questions it is very difficult to provide appropriate feedback.

f) Faculty Expectations

It would appear from the foregoing that the level of difficulty of each topic is variable, and since the specific questions are unknown it is not possible for faculty to identify the specific cause of low scores on individual topics, or to determine whether the question itself or student learning is deficient. Discussions between coordinators revealed that faculty had definite expectations of their students, but these expectations were difficult to compare with FE performance. A survey of faculty expectations of student performance on the FE exam in three programs (Mechanical, Metallurgical and Mining Engineering), for the Winter 94, Fall 94 and Winter 95 semesters, revealed that students performed below faculty expectations. Table 8 illustrates the expectations of one departmental faculty of the ability of students with minimal competency to answer questions successfully in each of the ten morning and five afternoon topics of the FE examination. The average student's scores were above the faculty minimum expectation in seven of the fifteen topics, but overall the average total student score was disappointingly close to the faculty minimum expectation. It should be noted that faculty expectations were based only on a knowledge of sample FE questions, and that actual questions remained totally confidential.

Table 8 - Faculty Minimum Expectation and Student Average Performance for WS 94, FS 94 and WS95

AM Topic	**Chm**	**Fluid**	**Dyn**	**Elec. Circs**	**Eng. Econ**	**Mats**	**Math**	**Mech**	**Stat**	**Thrm**	**Total AM**
Faculty. Exp. %	75	50	25	25	50	70	65	50	50	50	51
Student Perf. %	72	44	42	41	55	73	57	36	55	41	47

PM Topic	**App. Math**	**Elec. Circ.**	**Eng. Econ.**	**Eng. Mech.**	**Therm/ Fluids**	**Total PM**	**Total AM +PM**
Faculty. Exp. %	60	20	50	30	30	38	42
Student Perf. %	51	31	48	36	30	39	42

g) Campus Engineering Assessment

In order to further investigate the actual level of student performance, the Campus Engineering Assessment exam (CEA)was constructed by a group of coordinators, and used as a practice FE examination for volunteer students in April, 1996. The 30 volunteer students took the FE examination a week after taking the CEA thus permitting a correlation of student performance on the CEA with known questions, and the morning FE, with unknown questions. The CEA exam was based on the ten morning topics, and administered under similar condition to those used in the FE. The data for this test is plotted in Figure 3, and the average score for the CEA was 44% compared to an average score of 60% on the morning topics of the FE. The overall correlation

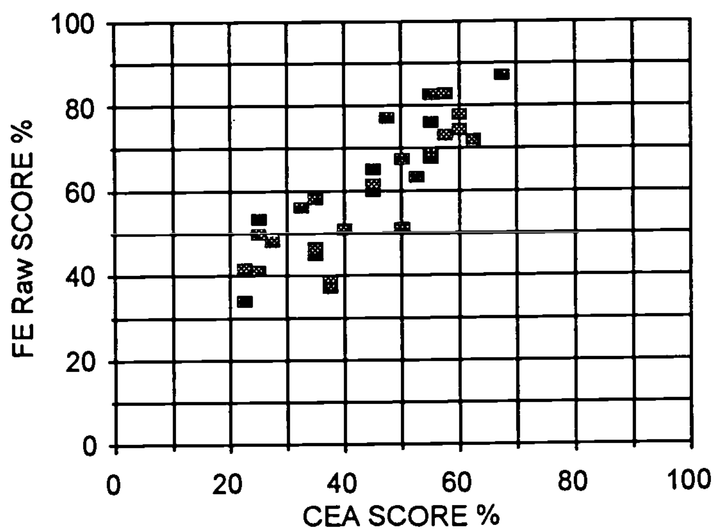


Figure 3. FE v. CEA Plot for WS 96

between the FE and CEA instruments for the volunteer group had a r^2 value of 0.74, but the correlation for individual topics was much lower. The students who took the CEA had a score 7% higher on the morning FE than the general campus population. This could be a function of the character of the volunteer group, or reflect the value of a practice examination.

A comparison of the performance of students on the individual morning topics is shown in Figure 4 for the sample group on the CEA and on the morning FE, and for the whole UMR group on the morning FE. In no topic did students in the volunteer group do better in the CEA than in the FE morning examination, and the largest discrepancies between CEA and FE results were in mathematics, dynamics, and circuits. It can be seen that the sample group outperformed the UMR group on all topics on the FE exam, with the largest differences being apparent in chemistry and thermodynamics. Again it is evident that students at UMR do well in chemistry and economics, and poorly in circuits.

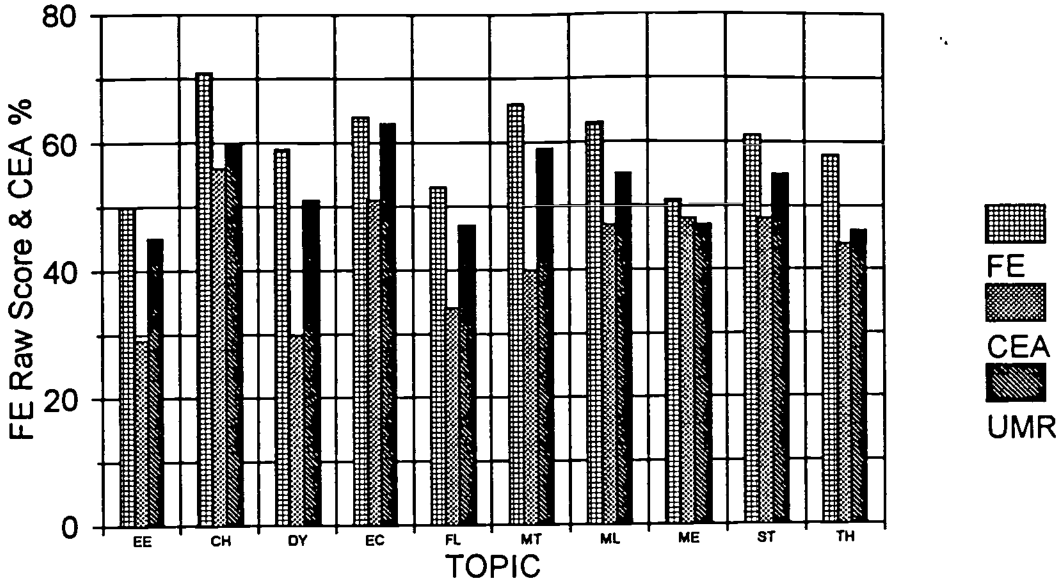


Figure 4. Comparison of FE and CEA Topics

The relationships between GPA, and FE and CEA, are shown in Figure 5, and weak correlations were evident for both test scores with student campus GPA. As expected, the FE score and the CEA scores do trend upward with GPA. The obvious scatter in the data could be attributed to the seriousness with which each student approached the mandatory FE examination, but since the CEA was voluntary that explanation is difficult to justify.

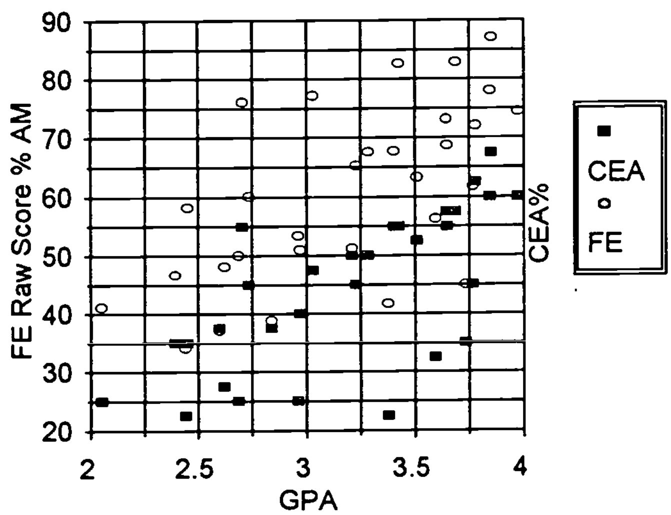


Figure 5. FE Raw Score and CEA % v. Student GPA

An examination of the results for the 40 individual questions of the CEA revealed a success rate varying from 15% on an AC circuit question to 85% on a chemistry equilibrium question. The distribution of correctly answered questions is shown in Figure 6, and it can be seen that 25% of

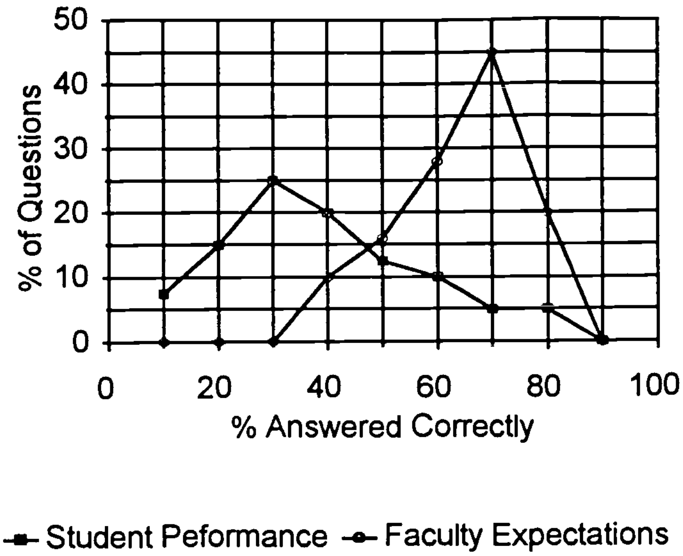


Figure 6. Distribution of Correctly Answered Questions

all questions were answered correctly by only 30% of the students, and only 33% of the questions were answered correctly at least 50% of the time. Surprising results included the fact that 67% of the students were unable to utilize the definition of pH, to calculate a 95% confidence interval, or to solve a simple DC circuit. Six department coordinators, not involved in the preparation of the CEA, provided estimates of the expected performance of their students on each question, and the range of expected correct answers was 35% to 85% with an overall CEA expectation of 67%. The average faculty expectation is also plotted on Figure 6, and it can be seen to be significantly higher than the student performance. It is interesting to note that while students performed at approximately the same level in the FE as faculty expectations, there was a significant difference in terms of the CEA. A possible inference is that the unknown FE questions are pitched at a lower level than faculty anticipate. The faculty responsible for the CEA had endeavored to make the CEA easier than the perceived FE question level anticipating a success level of 75-85% on each question, compared with the 45-55% success rate typical of the FE morning session. It was disconcerting for the faculty involved to determine that students were not performing at the level they anticipated, and that the FE appeared significantly less demanding than suspected. Several faculty, not involved in the FIPSE project, also evaluated the CEA questions, and their estimates of overall student success ranged from 60% to 80%.Thus there are concerns relating to both the standard of the FE exam questions and the high pass rate coupled with a low raw scores.

h) Curriculum-based Indicators of FE Performance

A project to investigate possible relationships between single and combinations of selected courses with FE performance in the Civil Engineering department was undertaken by Dr. Paul Munger during the summer session of 1996. The data analysis examined the correlation between Winter 96 FE score and the math, engineering economy, fluids, capstone design, and statics course grades for individual students. No meaningful relationships were determined, but it was found that the probability of a student passing the FE exam was strongly correlated to a parameter indicating the departmental GPA ranking of the student. For the semester data evaluated, the probability of a student in the top 40% of the class, based on departmental course GPA, passing the FE was 0.97 or better, while students in the bottom 10% of the class had a passing probability of 0.93. The strikingly high probability of passing is obviously a reflection of the fact that the pass rate in Civil Engineering for WS 96 was in fact 92%.

F. Summary and Conclusions

It is apparent that there is a great deal of useful information generated from the FE examination, and that currently that information is not being utilized by engineering programs. It is also apparent that use of the information as an indicator of student learning in engineering and science topics is compromised by the fact that a) the FE is not taken by all engineering students, b) students who are required to take the examination are typically not held accountable for the results, and c) the students who voluntarily take the FE exam, do so primarily to satisfy the preliminary requirement of the PE registration procedure. Hence the value of the FE qualification is significantly different for each engineering discipline. Thus the actual student population taking the exam and the exam scores confound the data analysis to a certain extent, and obscure the ability of the data to truly reflecting learning.

However, the project data has generated certain conclusions, which are of value. These conclusions, stated below, should be considered in conjunction with the limitations detailed in the preceding paragraph:

1. The results of the only nationally normed test of engineering learning do not correlate with individual student GPA or with grades earned on basic engineering courses.

2. Faculty expectations of student performance on FE topics typically exceeded the actual performance, although the faculty expectations were based on their knowledge of sample questions only.

3. The campus engineering programs were able to utilize FE data to identify topics in which students did not perform to expectation, but without detail of the topic and sub-topic questions, appropriate feedback and corrective action was very difficult.

4. The campus engineering programs identified subsets of the topics of the FE exam which were considered to more fairly represent the goals of the individual curricula. The scores in those subsets were typically only 5% higher for most programs than the overall scores.

5. A correlation was determined between the FE and campus CEA exams, and students who took the CEA were observed to have better scores on the FE than the general campus population.

6. From the CEA data, it was apparent that students performed at levels well below those

expected by faculty who generated the CEA questions and by other faculty who evaluated the CEA exam.

7. In recent years, the typical FE pass rate for UMR students has been 75%, and from the UMR data examined, it appears that approximately 43% was the minimum passing score. The fact that a student can fail to answer correctly more than half of the questions and still pass the FE is disturbing, especially in the light of the CEA data, which suggests that the FE questions are pitched at a lower level than faculty had perceived.

In summary, it can be stated that the Fundamentals of Engineering examination, in the form that existed between 1992 and 1996, could generate assessment data for engineering programs if the NCEES freely released the examination data. However, the individual campuses would have to ensure that a) students took the examination and b) took it seriously to enable the resulting FE data to be utilized. A further complication in the use of the data is that without direct knowledge of the FE questions, it is impossible to identify the cause of poor student performance in certain topics and sub-topics. Thus to make the FE data of real value in terms of outcomes assessment, passing the FE would have to be part of the graduation requirement for engineering programs, and all the examination questions would have to be released after each examination.

In order to ensure the widest distribution of the data generated by this project, papers will be submitted to the American Society for Engineering Education, and to the American Association of Higher Education - Assessment. In addition, the author will endeavor to make presentations to interested engineering schools to further discussion on engineering assessment techniques which will assist programs to provide the appropriate and necessary data for engineering accreditation under the Accreditation Board for Engineering and Technology 2000 criteria.

G. Appendices

Appendix A - Project Personnel

Appendix B - Sample FE Examination Reports

Appendix C - Sample of the Campus Engineering Assessment Examination

Appendix D - Budget

Appendix A - Project Personnel

Table A1- Project Coordinators

Dr. David Barr	Professor	Geological Engineering
Dr. Ron Fannin	Professor & Chair	Basic Engineering
Dr. Charles Heisch	Research Engineer	Chemistry
Dr. William Ingram	Professor & Chair	Mathematics
Dr. Arvind Kumar	Professor & Chair	Nuclear Engineering
Dr. Robert Medrow	Associate Profressor	Mechanical & Aeronautical Eng.
Dr. Robert Moore	Professor & Chair	Ceramic Engineering
Dr. Paul Munger	Professor	Civil Engineering
Dr. Bill Omurtag	Professor & Chair	Engineering Management
Dr. William Parks	Associate Professor	Physics
Dr. Ken Robertson	Associate Professor	Chemistry
Dr. Stephen Rosen	Professor & Chair	Chemical Engineering
Dr. Keith Stanek	Professor & Chair	Electrical Enginering
Dr. John L. Watson	Professor & Chair	Metallurgical Engineering
Dr. John Wilson	Professor & Chair	Mining Engineering

Table A - 2 Project Facilitators

Dr. Bassem Armaly	Professor & Chair	Mechanical & Aerospace Engineering
Dr. Jerry Bayless	Associate Dean	School of Engineering
Dr. John Fulton	Dean	College of Art & Sciences
Dr. Edwin Hale	Professor & Chair	Physics
Dr. Ron Kohser	Assistant Dean	School of Mines & Metallurgy
Dr. Gary Patterson	Associate Dean	School of Engineering
Dr. John Rockaway	Professor & Chair	Geological Engineering
Dr. Richard Stephenson	Professor & Chair	Civil Engineering
Dr. Nicholas Tsoulfanidis	Assistant Dean	School of Mines & Metallurgy

Appendix B - FE Examination Reports (Levels 1, 2 and 3)

Level 1 - NCEES data from April, 1995 for Metallurgical Engineering is attached.

Level 2 - FIPSE data from October, 1995 for Metallurgical Engineering is attached.

Level 3 - FIPSE data from October, 1995 for Applied Math for Metallurgical Engineering is attached

National Council of Examiners
for Engineering and Surveying (NCEES)
Fundamentals of Engineering Examination
APRIL 1995 Administration

Report 6
Subject Matter Report by Major/All Majors Combined
Including State and National Norms for Each

All Examinees

Board: MISSOURI 05/25/95
Special Code: University of Missouri-Rolla Major: Metallurgical

	---Specified Major Only---			--All Majors Combined---		
	Special Code	State	Nat'l	Special Code	State	Nat'l
No. Examinees Taking	11	11	68	294	620	29063
No. Examinees Passing	5	5	49	209	451	21002
% Examinees Passing	45%	45%	72%	71%	73%	72%

	Number of Exam Questions	Special Code Ave. No. Correct	State Ave. No. Correct	Nat'l Ave. No. Correct	Special Code Ave. No. Correct	State Ave. No. Correct	Nat'l Ave. No. Correct
AM Subject (1 point each)							
Chemistry	14	8.2	8.2	8.2	6.1	6.0	6.1
Dynamics	14	5.2	5.2	5.9	6.7	6.8	6.8
Elect Circuits	14	4.0	4.0	5.9	6.0	6.0	5.9
Engr Economics	11	4.6	4.6	5.7	6.1	6.1	6.1
Fluid Mech	14	5.5	5.5	5.8	6.6	6.5	6.4
Mat Sci/St Mat	14	8.5	8.5	9.0	6.6	6.3	6.3
Mathematics	20	7.6	7.6	8.6	8.9	9.0	9.0
Mech of Matls	11	2.3	2.3	3.8	4.1	4.1	4.2
Statics	14	5.7	5.7	6.7	7.0	7.2	7.0
Thermodynamics	14	3.4	3.4	5.4	5.1	5.3	5.5
PM Subject (2 points each)							
App Mathematics	20	7.3	7.3	9.6	9.7	10.0	9.8
Elect Circuits	10	2.2	2.2	3.8	4.1	4.1	4.1
Engr Economics	10	4.1	4.1	5.1	5.8	5.7	5.9
Engr Mech	20	6.4	6.4	8.0	8.2	8.4	8.6
Thermo/Fluids	10	3.0	3.0	3.6	3.6	3.7	3.8

People in the MT ENG department

SSN	NAME	REG #	DEPT	MORNING										AFTERNOON							
				MATH	CIRC	FLMC	THRM	DYNX	STTX	CHEM	MCKY	ECON	MATR	ENMC	AMTH	CIRC	ECON	FLMC	CUM	SC_S	PASS
			MT ENG	9	3	8	7	7	5	10	3	5	9	5	10	2	4	5	118	71	PASS
			MT ENG	12	8	1	4	5	5	9	5	6	9	4	9	2	3	3	106	69	FAIL
			MT ENG	19	12	12	11	12	12	13	7	11	14	14	18	8	7	7	231	88	PASS
			MT ENG	11	6	6	7	6	6	7	7	9	10	2	17	7	7	4	149	76	PASS
			MT ENG	15	10	3	5	6	11	12	5	9	12	9	19	2	9	3	172	79	PASS
			MT ENG	13	6	9	5	5	8	9	2	8	5	2	13	4	5	6	130	73	PASS
			MT ENG	12	13	5	8	9	10	11	6	10	13	9	16	8	6	5	185	81	PASS
			MT ENG	17	12	13	12	9	6	13	6	10	12	8	20	8	9	7	214	85	PASS
			MT ENG	11	8	9	8	7	7	7	5	6	12	12	16	4	3	4	158	77	PASS
			COUNT=	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	
			MEAN=	13	9	7	7	7	8	10	5	8	11	7	15	5	6	5	163	78	

N(MT ENG)= 9
PASS= 8 %PASS= 89%
FAIL= 1 %FAIL= 11%

Field Name Documentation

Morning

MATH --> MATHEMATICS-AM
CIRC --> ELECTRICAL CIRCUITS-AM
FLMC --> FLUID MECHANICS-AM
THRM --> THERMODYNAMICS-AM
DYNX --> DYNAMICS-AM
STTX --> STATICS-AM
CHEM --> CHEMISTRY-AM
MCKY --> MECHANICS OF MATERIALS-AM
ECON --> ENGINEERING ECONOMICS-AM
MATR --> MATERIALS SCI/STRUCTURE OF MATTER-AM

Afternoon

ENMC --> ENGINEERING MECHANICS-PM
AMTH --> APPLIED MATHEMATICS-PM
CIRC --> ELECTRICAL CIRCUITS-PM
ECON --> ENGINEERING ECONOMICS-PM
FLMC --> THERMODYNAMICS/FLUID MECHANICS-PM

CUM --> CUMULATIVE TOTAL
SC_S --> SCALED SCORE

9510 EIT CONTENT AREA REPORT - APPLIED MATH - BY DEPARTMENT: MT ENG

SUBJECT:APPLIED MATH PM

ITEM DETAIL - TOTAL POSSIBLE=1

TOPIC:	DEPT AVG	% CORRECT FACULTY EXPECTATIONS	CAMPUS	SCHOOL OF ENGR	SCHOOL OF M&M	MEDIAN	MODE	S.D.
ANALYTIC GEOMETRY(1):	1		0.62	0.64	0.55	1	1	0
ANALYTIC GEOMETRY(2):	1		0.8	0.84	0.69	1	1	0
ANALYTIC GEOMETRY(3):	0.67		0.6	0.63	0.48	1	1	0.5
ANALYTIC GEOMETRY(4):	0.89		0.86	0.9	0.75	1	1	0.33
ANALYTIC GEOMETRY(5):	0.33		0.26	0.28	0.19	0	0	0.5
DIFFERENTIAL EQUATIONS(1):	0.89		0.7	0.71	0.64	1	1	0.33
DIFFERENTIAL EQUATIONS(2):	0.67		0.57	0.63	0.39	1	1	0.5
DIFFERENTIAL EQUATIONS(3):	0.44		0.25	0.27	0.18	0	0	0.53
DIFFERENTIAL CALCULUS(1):	0.89		0.76	0.78	0.69	1	1	0.33
DIFFERENTIAL CALCULUS(2):	0.78		0.63	0.63	0.64	1	1	0.44
DIFFERENTIAL CALCULUS(3):	0.78		0.71	0.75	0.57	1	1	0.44
DIFFERENTIAL CALCULUS(4):	1		0.82	0.83	0.78	1	1	0.44
DIFFERENTIAL CALCULUS(5):	0.78		0.63	0.66	0.54	1	1	0.44
DIFFERENTIAL CALCULUS(6):	0.89		0.71	0.72	0.7	1	1	0.44
DIFFERENTIAL CALCULUS(7):	0.78		0.86	0.88	0.82	1	1	0.44
INTEGRAL CALCULUS(1):	0.78		0.81	0.83	0.73	1	1	0.44
INTEGRAL CALCULUS(2):	1		0.87	0.89	0.81	1	1	0
PROBABILITY & STATISTICS(1):	0.44		0.31	0.32	0.27	0	0	0.53
PROBABILITY & STATISTICS(2):	0.89		0.65	0.65	0.67	1	1	0.33
PROBABILITY & STATISTICS(3):	0.44		0.64	0.68	0.52	0	0	0.53

SUBJECT AREA - TOTAL POSSIBLE=20		EXPECTATIONS						
DEPT:	15.33					16	16	3.87
CAMPUS:			13.07			14	16	4.01
SCHOOL OF ENGR:				13.5		14	14	3.75
SCHOOL OF M&M:					11.6	11	11	4.52
NUMBER OF STUDENTS:	9		294	227	67			

COLUMN DEFINITIONS:

DEPARTMENT AVERAGE=NUMBER OF STUDENTS ANSWERING CORRECTLY IN THE DEPARTMENT/TOTAL NUMBER OF STUDENTS IN THE DEPARTMENT.

MODE=THE MOST FREQUENT VALUE. IF MORE THAN ONE MODE SMALLEST IS RETURNED.

MEDIAN=THE MEDIAN OR THE 50TH PERCENTILE.

AVG=ARITHMETIC MEAN(AVERAGE) THE SUM OF THE SCORES/ NUMBER OF SCORES.

S.D.=STANDARD DEVIATION, THE SQUARE ROOT OF THE VARIANCE, USED AS A MEASURE OF DISPERSION OF A GROUP OF SCORES.

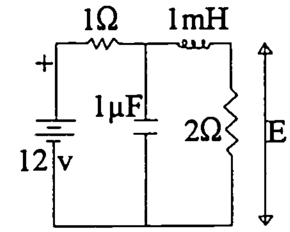
Appendix C - CEA Examination

The Campus Engineering Assessment was given to volunteer students under similar conditions to those used for the FE exam. The CEA was formatted in three versions, and students were permitted to use calculators and the FE Reference Handbook. The time permitted for the exam was 75 minutes.

Campus Engineering Assessment - 1996

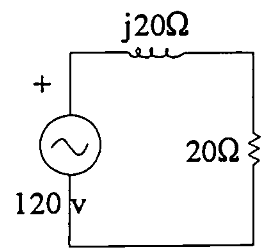
Name ____________ Student Number________

Answer all questions in the one hour time period allotted. The EIT Engineering Reference Book may be used, as may any calculator.



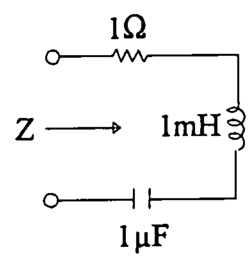
1. For the dc circuit shown, the steady state voltage across the 2 Ω resistor, E, is most nearly:

A) 0.0 volts B) 4.0 volts C) 6.0 volts D) 8.0 volts
E) 12.0 volts



2. For the ac circuit shown, all component values are given in ohms at the source frequency. The ac steady state power supplied to the 20Ω resistor is most nearly:

A) 60 W B) 180 W C) 240 W D) 360 W
E) 720 W



3. For the circuit shown, the frequency at which net impedances at the terminals of the circuit, Z, is a real quantity, is most nearly:

A) 159 Hz B) 1000 Hz C) 5033 Hz D) 6280 Hz
E) 31,623 Hz

4. A covalently bonded structure requires

A) electrons to be donated by one atom to another
B) atoms must have an equal number of electrons.
C) eight electrons to complete the outer orbit.
D) electrons must divide their time between the bonded atoms.
E) an even number of electrons in the bonding atoms.

5. Which number is closest to the number of atoms in 5 lb. of copper wire (at. wt. Copper = 63.546 g).

A) 4.7 E22 B) 7.6 E23 C) 2.2 E25 (D) 3.8 E25 (E) 1.4 E27

6. In neutral water of pH 7, the concentration of hydrogen ions is:

A) zero B) 0.007 % C) 10^{+7} D) 10^{-12} % E) 10^{-5}%

7. The equation $M\ C_2H_5OH + Q\ O_2 \rightleftharpoons R\ CO_2 + S\ H_2O$ is balanced when:

A) M = Q = 1, R = 2, S = 3
B) M = 1, Q = 6, R = 1, S = 1
C) M = 1, Q = 3, R = 2, S = 3
D) M = Q = 2, R = 2, S = 5
E) M = Q = 2, R = 5, S = 5

8. In the reaction **A** + **B** $\rightleftharpoons$ **C**, equilibrium is achieved when

A) Either all of **A** or all of **B** is consumed making **C**.
B) Both **A** and **B** are completely consumed making **C**.
C) The weight of **A** plus **B** equals the weight of **C**.
D) One-half (½) the weight of **A** plus **B** equals the weight of **C**.
E) The rate of decomposition of **C** to form **A** and **B** equals the rate of formation of **C** from **A** and **B**.

9. What is the valence state (oxidation number) of boron in H_3BO_3.

A) +3 B) - 2 C) + 2 D) - 3 E) + 1

10. A locomotive traveling at 100 ft/sec locks its wheels and skids 1000 ft before stopping. If the deceleration is constant, the locomotive will come to a stand still in:

A) 5 sec B) 10 sec C) 20 sec D) 40 sec E) 50 sec

11. A 3.22 lbm ball is thrown straight up with an initial velocity of 100 ft/sec. Neglecting air friction, the total energy of the ball at an elevation where the velocity is 50 ft/sec is:

A) 125 ft-lbf B) 250 ft lbf C) 322 ft-lbf D) 500 ft-lbf E) 16100 ft-lbf

12. A 100 lbm desk is pushed 10 ft across a room at constant velocity. If the coefficient of sliding friction between the desk and the floor is 0.1, then the work done is:

(A) 100 ft-lbf B) 500 ft-lbf C) 1000 ft-lbf D) 3220 ft-lbf E) 10000 ft-lbf

13. Mr. Ramsey is a very successful engineer. He graduated from engineering school 30 years ago and, because of his engineering work over that time, is now a multi-millionaire. Being thankful, he wishes to set up a permanent scholarship at his alma mater that will provide an annual stipend of $5000. If such an endowment can be established and return an annual rate of interest of 4%, how much does he need to contribute at this time to establish this permanent scholarship (stipend)?

A) $49,996 B) $54,996 C) $125,000 D) $130,000 E) $500,000

14. James has just been notified that he is the inheritor of $10,000 right now. In addition he will receive an additional $10,000 at the end of each year for the next 25 years. What is his inheritance worth right now if money will draw interest at 8% compounded annually?

A) $106,735 B) $106,748 C)$116,748 D) $260,000 E) $731,059

15. Four years ago XYZ Corporation purchased a piece of equipment that cost $75,000. At that time its expected life was 10 years and its estimated salvage value was $25,000. The corporation has been depreciating the investment using straight-line depreciation and has just deducted the fourth year's depreciation. A new piece of equipment is available on the market that is much more efficient. It costs $90,000, has a life of 15 years and an expected salvage value of $20,000. What is the book value of the present machine?

A) $45,000 B) $55,000 C) $60,000 D) $66,000 E) $70,000

16. A state highway department is proposing to relocate a section of road where a number of accidents have occurred every year. The cost of the new construction will be $1,200,000. It is expected that the new road will last 50 years, at which time it will be worth nothing. Annual maintenance costs for upkeep of the road are estimated to be $25,000. As a result of the new road, users of the road are expected to save $160,000 each year through reductions in their costs. The present owners of the land will lose an estimated $30,000 per year due to the loss of agricultural income. As a government agency, the state uses a minimum rate of return of 8%. What is the benefit/cost ratio?

A) 1.05 B) 1.06 C) 1.07 D) 2.65 E) 4.38

17. Water to a depth of 6 m is stored behind a dam of height 10 m and width 50 m. Calculate the total force on the dam:

A) 5.8×10^6 N B) 8.8×10^6 N C) 5.9×10^7 N D) 8.6×10^7 N
E) 1.2×10^8 N

18. The flow of a liquid in a 10 cm diameter pipeline is known to be in the turbulent regime. If the viscosity of the liquid is 1 centipoise, determine the minimum flow velocity:

A) 0.1 cm/s B) 5.0 cm/s C) 50 cm/s D) 150 cm/s E) 250 m/s

19. The reading of a venturi meter is seen to double due to process changes. What variation in flow has occurred ?

A) None B) Flow halved C) Flow increased by $\sqrt{2}$ D) Flow doubled
E) Flow squared

20. Calculate the velocity of a liquid discharging from a sharp edged orifice, of area 2 cm^2, located 1m below the surface of the liquid.

A) 1.3 m/s B) 2.2 m/s C) 2.7 m/s D) 4.4 m/s E) Cannot be determined

21. A cylindrical drum of diameter 1m and length 3m is placed horizontally and filled to a height of 25cm with water. Calculate the weight of water in the drum.

A) 460 kg B) 590 kg C) 645 kg D) 785 kg E) 1000 kg

22. The displacement (x) of a component with time (t) as a result of an applied force is given by the expression $x = t^3/3 - t^2 - 3t$. Determine the maximum displacement of the component:

A) -9 B) -1 C) 0 D) 3 E) 5/3

23. The acceleration of an initially stationary aircraft is 2.0 m/s^2, calculate the distance covered by the aircraft in 1 minute:

A) 120 m B) 367 m C) 1175 m D) 3600 m E) 7200 m

24. The temperature (T °C) response of a furnace with time (t) is considered to be a first order process which is represented by the equation $dT/dt = k(120 - T)$ where k is the rate constant k, which has a value of 0.5 min^{-1}. If the initial temperature is 0 °C, determine the temperature of the process at a time of 45 seconds:

A) 37.5 °C B) 47.2 °C C) 72.8 °C D) 120 °C E) 157.5 °C

25. The starting salaries of engineers are normally distributed and the average has been determined to be $35,450 with a standard deviation of $3,200. Calculate the salary of engineers at the 95 percentile of the salary range:

A) $29,050 B) $32,250 C) $35,450 D) $38,650 E) $41,850

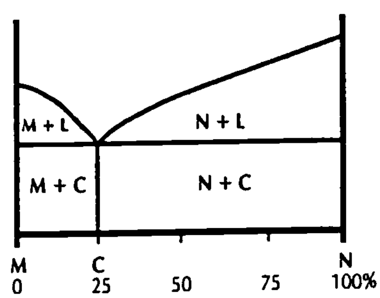
26. If the manufacturing costs of a complex component are equal to $3x^{0.5}$ where x is the number of components manufactured per day, and the material costs are 3x - 3, determine the production rate where the material and manufacturing costs are equal:

A) 0.4 B) 1.2 C) 1.8 D) 2.6 E) 3.0

27. In body centered cubic structures, along which feature of the cube are atoms presumed to make contact?

A) Edge B) Body Diagonal C) Nowhere D) All Directions E) Face Diagonal

28. The compound marked C on the phase diagram below has a composition of:



A) 25% C B) 25% M, 75% N C) 50% M, 50% N D) 75% M, 25% N
E) Cannot be determined.

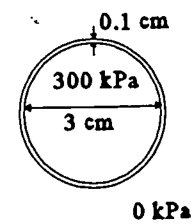
29. Metals usually form what kind of crystalline structures:

A) Monoclinic B) Amorphous C) Sheet D) Electronic E) Close Packed

30. Select the material showing the greatest ductility:

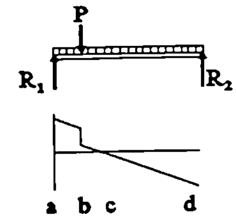
A) Zinc B) Glass C) Wood D) Aluminum E) Teflon

31. As shown, the inside diameter of the thin-walled cylinder is 3 cm and the wall thickness is 0.1 cm. For the internal and external pressures shown (300 kPa and 0 kPa respectively), the tensile stress in the cylinder wall is:



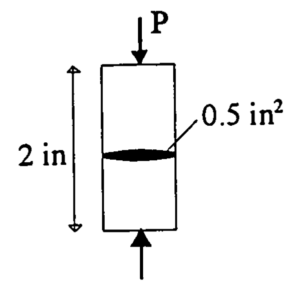
A) 5 kPa B) 10 kPa C) 300 kPa D) 4500 kPa E) 9000 kPa

32. A beam loaded with both a distributed load and a concentrated load is shown, along with the resulting shear diagram. The maximum bending moment occurs at:



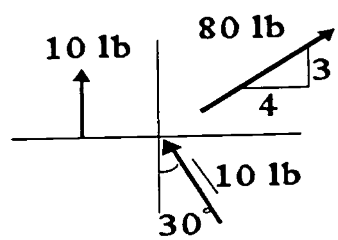
A) location a B) location b C) location c D) location d E) none of the preceding

33. Prior to the application of the load P, the length of the aluminum cylinder shown is 2 inches. If P is 500 lbf and the modulus of elasticity for aluminum is 10×10^6 lbf/in^2, application of the load reduces the cylinder's length by:



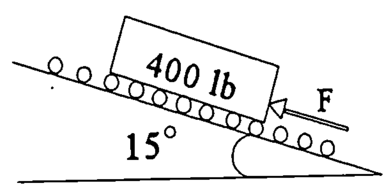
A) 0.000025 in B) 0.00005 in C) 0.0001 in
D) 0.0002 in E) 0.0004 in

34. The resultant force of the coplanar force system shown below is most nearly:



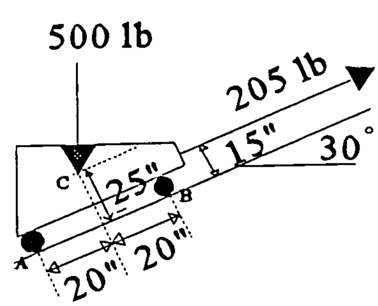
A) 0 lb B) 80 lb C) 90 lb D) 100 lb
E) 126 lb

35. The magnitude of the smallest force F which will maintain the package shown in equilibrium is most nearly:



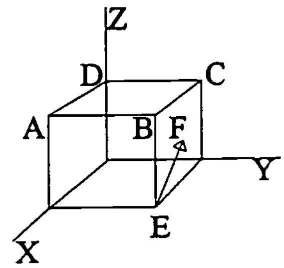
A) 0.0 lb B) 103.6 lb C) 200 lb D) 386.4 lb
E) 400 lb

36. A car and its load weighs 500 lbs and has its center of gravity at C. The wheels are free to roll, and the car is held in equilibrium by the cable with a tension of 205 lbs. The normal reaction of the wheels B is most nearly:



A) 0 lb B) 60 lb C) 137 lb D) 217 lb
E) 293 lb

37. The cube of side 2 feet is acted upon by force $F = -70.71\,\hat{i} + 70.71\,\hat{k}$ as shown below. The moment of F about point A is:



A) $141\,\hat{i} + 141\,\hat{k}$ B) $141\,\hat{i} + 141\,\hat{j} + 141\,\hat{k}$

C) 0.00 D) $141\,\hat{i} + 141\,\hat{j}$ E) $141\,\hat{k}$

38. When both the volume and the pressure of an ideal (perfect) gas are doubled, the absolute temperature is:

A) quadrupled B) doubled C) constant D) halved E) quartered

39. The net entropy change in the universe during a closed (fixed mass) system process is

A) undefined B) a function of the system pressure C) zero
D) equal to or greater than zero E) equal to or less than zero

40. Which of the following statements about the flow of gas through an insulated nozzle is most accurate?

A) The upstream and downstream enthalpies are the same.
B) The temperature of the gas increases sharply as it flows through the nozzle.
C) The upstream and downstream densities are equal.
D) The pressure of the gas increases sharply as it flows through the nozzle.
E) Per unit mass, the downstream kinetic energy is greater than the upstream kinetic energy.

Appendix D - Budget Expenditures

The FIPSE grant account original budget and expenditures, the UMR match account expenditures, and the extension budget are detailed in Tables A, B and C respectively. It can be seen from Table A that the original budget of $226,000 was underspent by $32,251 and that salaries and consultant fee were the major areas where funds were not fully committed. This was due to the resignation of Dr. Leininger and the subsequent part-time coordination of the project by Dr. Watson, and to the non-use of consultants to analyse the results of the project.

The UMR match for the project is presented in Table B, and it is apparent that UMR expended $74,969 during the period 8-92 through 12-96. This is equivalent to 38.5% of the project expenditures, and represents the level of the original budget match. The no-cost extension budget is presented in Table C for 1996, and again the underspending was associated with salaries and consultant fee.

Table A - FIPSE Grant Account Expenses 8-92 through 12-96

BUDGET ITEM	ORIGINAL BUDGET	YR1 EXPENSE	YR2 EXPENSE	YR3 EXPENSE	EXT EXPENSE	TOTAL EXPENSE	BALANCE
I.DIRECT COSTS							
1.SALARY & WAGE							
1.A.DIRECTOR		10,921	40,689	25,501	7,211	84,322	
1.B.FACULTY		0	36,612	0	17,756	54,368	
1.C.SECRETARY		0	7,133	3,599	0	10,732	
1.D.STUDENT		0	0	0	0	0	
1.E.DATA BASE		0	0	23,596	0	23,596	
1.F.OTHER		0	0	0	0	0	
SUBTOTAL S&W:	184,838	10,921	84,434	52,696	24,968	173,019	11,819
2.BENEFITS							
2.A.DIRECTOR		1,848	3,255	2,040	1,449	8,592	
2.B.FACULTY		0	2,929	0	0	2,929	
2.C.SECRETARY		0	571	288	0	859	
2.D.STUDENT		0	0	0	0	0	
2.E.DATA BASE		0	0	0	0	0	
2.F.OTHER		0	0	0	0	0	
SUBTOTAL BENEFITS:	14,662	1,848	6,755	2,328	1,449	12,380	2,282
3.TRAVEL	7,000	856	3,144	2,000	0	6,000	1,000
4.MATERIAL & SUPPLIES	7,000	242	346	653	109	1,350	5,650
5.CONSULTANT	12,500	0	500	500	0	1,000	11,500
SUBTOTAL 3-5:	26,500	1,098	3,990	3,153	109	8,350	18,150
TOTAL DIRECT:	$226,000	$13,867	$95,179	$58,177	$26,525	$193,749	$32,251

Table B - UMR FIPSE Match Account Expenses 8-92 through 12-96

BUDGET ITEM	YR1 EXPENSE	YR2 EXPENSE	YR3 EXPENSE	EXT EXPENSE	TOTAL EXPENSE
I.DIRECT COSTS					
1.SALARY & WAGE					
1.A.DIRECTOR	5,125	5,813	16,313		27,250
1.B.FACULTY	0	5,888	0		5,888
1.C.SECRETARY	4,254	4,249	4,300		12,803
1.D.STUDENT	2,466	1,460	660		4,586
1.E.DATA BASE	0	0	0		0
1.F.OTHER	0	0	0		0
SUBTOTAL S&W:	11,845	17,410	21,272	0	50,527
2.BENEFITS					
2.A.DIRECTOR	1,591	1,095	2,147		4,833
2.B.FACULTY	0	4,669	0	3,240	7,909
2.C.SECRETARY	795	2,030	871		3,696
2.D.STUDENT	38	26	8		71
2.E.DATA BASE	0	0	0		0
2.F.OTHER	356	6,142	204		6,702
SUBTOTAL BENEFITS:	2,779	13,962	3,230	3,240	23,210
3.TRAVEL	0	1,052	180		1,232
4.MATERIAL & SUPPLIES	0	0	0		0
5.CONSULTANT	0	0	0		0
SUBTOTAL 3-5:	0	1,052	180	0	1,232
TOTAL DIRECT:	$14,624	$32,424	$24,682	$3,240	$74,969

Table C - Extension Budget 01-01-96 through 12-31-96

BUDGET ITEM	UMR BUDGETED	UMR ACTUAL	UMR BALANC	FIPSE BUDGETED	FIPSE ACTUAL	FIPSE BALANCE
I.DIRECT COSTS						
1.SALARY & WAGE						
1.A.DIRECTOR	0	0	0	5,337	7,211	(1,874)
1.B.FACULTY	0	0	0	35,000	17,756	17,244
1.C.SECRETARY	0	0	0	0	0	0
1.D.STUDENT	0	0	0	0	0	0
1.E.DATA BASE	0	0	0	0	0	0
1.F.OTHER	0	0	0	0	0	0
SUBTOTAL S&W:	0	0	0	40,337	24,968	15,369
2.BENEFITS						
2.A.DIRECTOR	0	0	0	753	1,449	(696)
2.B.FACULTY	8,750	3,240	5,510	0	0	0
2.C.SECRETARY	0	0	0	0	0	0
2.D.STUDENT	0	0	0	0	0	0
2.E.DATA BASE	0	0	0	0	0	0
2.F.OTHER	0	0	0	0	0	0
SUBTOTAL BENEFITS:	8,750	3,240	5,510	753	1,449	(696)
3.TRAVEL	0	0	0	0	0	0
4.MATERIAL & SUPPLIES	0	0	0	1,000	109	891
5.CONSULTANT	0	0	0	3,000	0	3,000
SUBTOTAL 3-5:	0	0	0	4,000	109	3,891
TOTAL :	$8,750	$3,240	$5,510	$45,090	$26,525	$18,565